Section 6: Key Inquiry Topic – Ocean Health

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Stressed Out!

Focus
Threats to ocean health

Grade Level
7-8 (Life Science)

Focus Question
What stresses threaten the health of ocean ecosystems, and what may be done to reduce these stresses?

Learning Objectives
- Students will identify stresses that threaten the health of ocean ecosystems.
- Students will explain natural and human-caused processes that contribute to these stresses.
- Students will discuss actions that may be taken to reduce these stresses.

Materials
- (Optional) Materials for Scientific Posters: see Learning Procedure Note and Step 5)
- (Optional) Materials for Constructing a Tabletop Shrimp Support Module (TSSM): see Learning Procedure Note and Step 6)
  - Copies of *Tabletop Shrimp Support System Construction Guide*, one copy for each student group
  - Materials for constructing TSSM modules:

Materials for one TSSM:
- 1 - 1 quart glass canning jar
- 3 - plastic containers, 1 quart capacity or larger
- 12 (approximately) - River pebbles, about grape-size; enough to cover the bottom of the glass jar in a single layer
- 3-4 - small shells
- 1 - Amano shrimp, *Caridina multidentata* (from an aquarium store)
- 4 - aquatic snails, each less than 1 cm overall length
- 8-inch stem of hornwort (*Ceratophyllum demersum*; from an aquarium store)
- Duckweed, approximately 2 inches x 2 inches (from an aquarium store or local pond)
- 2-8 - Amphipods (from a local pond)

Materials that may be shared by several groups:
- Fishnet or kitchen strainer
- Dechlorinating solution (for treating tap water; from an aquarium store)
- Solution of freshwater minerals (*e.g.*, "cichlid salts;" from an aquarium store)
- Calcium carbonate powder (from an aquarium store)
- Tablespoon measure
- Pond sludge
- Plastic bucket, 1 gallon or larger capacity

Audiovisual Materials
- None

Teaching Time
Two or three 45-minute class periods plus time for student research; additional time will be required for optional activities (see Learning Procedure Note)

Seating Arrangement
Six groups of students

Maximum Number of Students
30

Key Words and Concepts
Ocean health
Overfishing
Habitat destruction
Invasive species
Climate change
Pollution
Ocean acidification

Background Information
NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

> *"The great mass extinctions of the fossil record were a major creative force that provided entirely new kinds of opportunities for the subsequent explosive evolution and diversification of surviving clades. Today, the synergistic effects of human impacts are laying the groundwork for a comparably great Anthropocene mass extinction in the oceans with unknown ecological and evolutionary consequences. Synergistic effects of habitat destruction, overfishing, introduced species, warming, acidification, toxins, and massive runoff of nutrients are transforming once complex ecosystems like coral reefs and kelp forests into monotonous level bottoms, transforming clear and productive coastal seas into anoxic dead zones, and transforming complex food webs topped by big animals into simplified, microbially dominated ecosystems with boom and bust cycles of toxic dinoflagellate blooms, jellyfish, and disease. Rates of change are increasingly fast and*

nonlinear with sudden phase shifts to novel alternative community states. We can only guess at the kinds of organisms that will benefit from this mayhem that is radically altering the selective seascape far beyond the consequences of fishing or warming alone. The prospects are especially bleak for animals and plants compared with metabolically flexible microbes and algae. Halting and ultimately reversing these trends will require rapid and fundamental changes in fisheries, agricultural practice, and the emissions of greenhouse gases on a global scale."

– Dr. Jeremy Jackson, Scripps Institution of Oceanography, 2008

The health of Earth's ocean is simultaneously threatened by over-exploitation, destruction of habitats, invasive species, rising temperatures, and pollution. Most, if not all, of these threats are the result of human activity. An overview of these issues can be found in Diving Deeper, page 33, and are discussed in greater detail in Allsopp, Page, Johnston, and Santillo (2007) and Jackson (2008). Most of these threats involve entire ocean ecosystems, which are highly complex and are not well-understood. Since Earth's ocean occupies more than 70% of our planet and the entire ocean is being affected, these issues inevitably will affect the human species as well.

Despite their severity, many of the ocean health issues described in Diving Deeper are not widely accepted as pervasive and pressing problems requiring immediate attention. Part of the problem is a phenomenon called "shifting baselines," a term first used by fishery biologist Daniel Pauly. A baseline is a reference point that allows us to recognize and measure change. It's how certain things are at some point in time. Depending upon the reference point (baseline), a given change can be interpreted in radically different ways. For example, the number of salmon in the Columbia River in 2007 was about twice what it was in the 1930s, but only about 20% of what is was in the 1800s. Things look pretty good for the salmon if 1930 is the baseline; but not nearly as good compared to the 1800s. The idea is that some changes happen very gradually, so that we come to regard a changed condition as "normal." When this happens, the baseline has shifted. Shifting baselines are a serious problem, because they can lead us to accept a degraded ecosystem as normal—or even as an improvement (Olson, 2002).

Perceptions of coral reefs offer another example of shifting baselines. Many of Earth's coral reefs appear to be in serious trouble due to causes that include over-harvesting, pollution, disease, and climate change (Bellwood *et al.*, 2004). In the Caribbean, surveys of 302 sites between 1998 and 2000 show widespread recent mortality among shallow- (<5 m depth) and deepwater (> 5 m depth) corals. Remote reefs showed as much degradation as reefs close to human coastal development, suggesting that the decline has probably resulted from multiple sources of long-term as well as short-term stress (Kramer, 2003). Despite these kinds of data and growing concern among marine scientists, visitors continue to be thrilled by the "abundance and diversity of life on coral reefs." So, people who have never seen a coral reef before may still find it to be spectacular, even though many species have disappeared and the corals are severely stressed.

This activity guides a student inquiry into stresses that threaten the health of ocean ecosystems, and actions that may be taken to reduce these stresses.

Limacina helicina, a free-swimming planktonic snail. These snails, known as pteropods, form a calcium carbonate shell and are an important food source in many marine food webs. As levels of dissolved CO_2 in sea water rise, skeletal growth rates of pteropods and other calcium-secreting organisms will be reduced due to the effects of dissolved CO_2 on ocean acidity. Image credit: Russ Hopcroft, UAF/NOAA. *http://www.noaanews.noaa.gov/stories2006/images/pteropod-limacina-helicina.jpg*

According to the Intergovernmental Panel on Climate Change (the leading provider of scientific advice to global policy makers), surface ocean pH is very likely to decrease by as much as 0.5 pH units by 2100, and is very likely to impair shell or exoskeleton formation in marine organisms such as corals, crabs, squids, marine snails, clams and oysters.

Large *Paragorgia* colonies on basalt substrate. From the Mountains in the Sea 2004. Image credit: NOAA. *http://oceanexplorer.noaa.gov/explorations/04mountains/logs/summary/media/paragorgia.html*

Unusual spiny crab spotted on NW Rota 1 volcano. Crabs are opportunistic predators at vent sites. The body of this crab is ~2 in. (~5 cm) across. Image credit: NOAA. *http://oceanexplorer.noaa.gov/explorations/04fire/logs/march30/media/spinycrab.html*

Learning Procedure

NOTE: This lesson includes two optional activities; one involving scientific communication (Step 5) and another involving experiment-based hypothesis testing (Step 6). These activities will add significantly to time requirements, but they are both fundamental elements of modern science and can be related to many other curriculum elements, which may justify allocating the extra time needed for their completion.

1. To prepare for this lesson:
   - Review introductory information on the NOAA Ship *Okeanos Explorer* at *http://oceanexplorer.noaa.gov/okeanos/welcome.html*. You may also want to consider having students complete some or all of the lesson, *To Boldly Go*….
   - Review *Ocean Health Overview* in Diving Deeper, page 33.
   - If you plan to use the optional scientific communication activity (Step 5), review Scientific Posters, page 202.
   - If you plan to use the optional experiment-based hypothesis testing activity (Step 6), review procedures in the *Tabletop Shrimp Support Modules Construction Guide,* page 203, and decide whether you will assemble the necessary materials or have students do this as part of their assignment. You may also want to review the original article, available online at *http://cachefly.oreilly.com/make/wp_aquanaut.pdf*.

   You may also want to check out Dr. Jeremy Jackson's *Brave New Ocean* presentation at *http://www.esi.utexas.edu/outreach/ols/lectures/Jackson/* (has links to a Webcast of the presentation) and/or *http://www.esi.utexas.edu/outreach/ols/clicks.php?id=41a* (PowerPoint® version of the presentation).

2. If you have not previously done so, briefly introduce the NOAA Ship *Okeanos Explorer*, emphasizing that this is the first Federal vessel specifically dedicated to exploring Earth's largely unknown ocean. Lead a discussion of reasons that ocean exploration is important, which should include understanding ocean health issues.

3. Tell students that their assignment is to research six major topics relevant to ocean health. Assign one of the following topics to each student group:

   Overfishing
   Habitat Destruction
   Invasive Species
   Toxins, Nutrients, Marine Debris
   Climate Change
   Ocean Acidification

   Instruct each group to prepare a report that includes:
   - Description of the problem;
   - Causes of the problem;
   - What needs to be done to correct the problem; and
   - What individuals can do to be part of the solution.

   There are several options for the format of the report, including an oral presentation, written report, PowerPoint™ or video presentation, or scientific poster (see Step 5). You may want to assign one or more of these formats or leave the choice to individual student groups, depending upon available time and resources.

At NW Eifuku volcano, mussels are so dense in some places that they obscure the bottom. The mussels are ~18 cm (7 in) long. The white galatheid crabs are ~6 cm (2.5 in) long. Image credit: NOAA. *http://oceanexplorer.noaa.gov/explorations/04fire/logs/april11/media/mussel_mound.html*

Although much of the debris concentrated in the "garbage patch" is composed of small bits of plastic not immediately visible to the naked eye, large items are occasionally observed. On Aug. 11, Scripps Institution of Oceanography SEAPLEX researchers encountered this large ghost net with tangled rope, net, plastic, and various biological organisms. Image courtesy of Scripps Institution of Oceanography. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1006/background/mantanet/media/ghost_net.html*

4. Have each group present and discuss results of their research. Since the assigned topics include problems that exist on a global scale, it may be difficult for students to identify solutions and meaningful individual action. If this problem arises, you may want to ask, "How do you eat an elephant?" The answer is, "One bite at a time." The key point is that these problems didn't happen all at once, so we probably shouldn't expect to fix them all at once. It may be helpful to consider specific individual decisions or actions that collectively contribute to the problem, and then how these decisions or actions could be modified to achieve a different outcome.

   Sharing the results of this discussion is important! Social networks used by students are an obvious possibility, as are a variety of school-to-school network projects. Please share your ideas with us, and let us know if you need our help (see Send Us Your Feedback, below).

5. (Optional) Have student groups prepare scientific posters about ocean health issues. See Page 202 for information about scientific posters. Arrange for students to present their posters to one or more audiences, such as other classes, parent groups, teachers, or community groups. Prior to beginning this activity, explain to students that communication is a fundamental part of modern science, and is essential for scientists to be able to learn and build on the results of others. In the case of ocean health issues, communication to non-scientific audiences is particularly important, because most people are unaware of these problems, and because most solutions involve public policy decisions that can be stimulated by large numbers of people expressing concern, or (even better) demanding that specific action be taken.

6. (Optional) The *Tabletop Shrimp Support Modules Construction Guide* is based on the Tabletop Shrimp Support Module (TSSM) described in an article titled *Ecosystems Engineering* by Martin John Brown, which appeared in Volume 10 of *Make* magazine. You can download a pdf of Brown's original article from *http://cachefly.oreilly.com/make/wp_aquanaut.pdf*. In a followup comment about the article, Brown says:

   > *"Most of the questions I've gotten have to do with switching ingredients or adding extra animals. The short answer is, DON'T. Making a bottle ecosystem is not the same as just throwing some stuff from the local pond in a jar, and it is nothing like running a regular fish tank. There is a reason for everything in the article."*

   The concept of this activity is to investigate the reasons for some of the individual components in the TSSM through experimental manipulation. The objectives of this activity are to give students experience in formulating and testing hypotheses, as well as identifying critical functions in aquatic ecosystems.

   Prior to beginning this activity, you will need to decide whether students will be required to obtain their own materials for constructing their TSSMs, or whether you will provide some or all of them. You will also need to decide whether students will work individually or in pairs. Larger groups are not recommended, because this will limit the number of replicate and control systems available, and these are essential to a well-designed experimental procedure.

Begin the activity with a class discussion that reviews TSSMs and the functions of individual components. Explain to students that you want to conduct a class experiment that tests hypotheses about one or more of these functions. Since the TSSM as described in the *Tabletop Shrimp Support Module Construction Guide* and in the original article by Brown is supposed to be a balanced system, hypotheses about the functions of components will be tested through experimental manipulations that alter this balance. Guide a class discussion to define one or more hypotheses and experimental manipulations that can test each hypothesis. Be sure to include controls, replicates, and avoid manipulating more than one variable at a time. A class of 30 students working in pairs would provide 15 TSSM systems, that could be allocated to 5 replicate controls and two sets of 5 replicate experimental systems to test two levels of a particular manipulation (*e.g.*, half as much calcium carbonate and no calcium carbonate). Plan to allow systems to equilibrate for at least one week after they are assembled before beginning experimental manipulations.

Randomly assign the systems to experimental and control groups. One technique for doing this is to give each system a number, beginning with "01," then "02," and so on. Then select a page from a telephone book and read the last two digits of the telephone numbers beginning at the top of the page. When the last two digits match the number of one of the systems, that system is assigned as a control. The next match is assigned to the first experimental group. The third match is assigned to the second experimental group. The fourth match is assigned as a control, and so on, consecutively assigning systems to control and experimental groups in rotation until all systems have been assigned.

Hypotheses and predictions should be based on students' knowledge of processes that occur in the TSSM system, such as photosynthesis and respiration. For example, students should realize that respiration produces carbon dioxide, and dissolved carbon dioxide will lower the pH of surrounding water (see Diving Deeper, page 41, for a demonstration of this). So, predictions about the function of calcium carbonate and/or shells might involve fluctuations in pH that could be measured in experimental and control systems. Here are a few other ideas:

- Keep experimental systems in the dark for 24 hours, then check pH & compare to pH of systems after 12 hours darkness & 12 hours light.
- Omit calcium carbonate and shells from some systems and repeat above, comparing results with systems that have calcium carbonate and shells.
- Double the amount of plant material.
- If you have an electronic dissolved oxygen meter, measure oxygen as well as pH in the above comparison.

Once data are collected, students should perform simple statistical analyses to evaluate the significance of any differences observed, and state whether the experimental results support or reject the hypothesis. After a particular hypothesis has been tested, you may have students restore all of the TSSMs to the "balanced" design, allow the systems to equilibrate, and test another hypothesis. Again, systems should be randomly assigned to experimental and control groups.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," "Human Activities," then "Environmental Issue" for links to resources about pollution, conservation, bycatch, sustainability, and policy.

The "Me" Connection

Have students write a brief essay describing how they could have a personal impact on an issue affecting ocean health.

Connections to Other Subjects

English/Language Arts, Social Sciences, Physical Science, Mathematics

Assessment

Students' reports and class discussions provide opportunities for assessment.

Extensions

1. Follow events aboard the *Okeanos Explorer* at *http://oceanexplorer.noaa.gov/okeanos/welcome.html*.

Multimedia Discovery Missions

http://www.oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lessons 12, 13 and 15 for interactive multimedia presentations and Learning Activities on Food, Water, and Medicine from the Sea; Ocean Pollution; and Seamounts.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(The following Lesson Plans are targeted toward Grades 7-8)

Treasures in Jeopardy (from the 2007 Cayman Island Twilight Zone Expedition)
http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/media/treasures.pdf

Focus: Conservation of deep-sea coral communities (Life Science)

Students will compare and contrast deep-sea coral communities with their shallow-water counterparts and explain at least three benefits associated with deep-sea coral communities. Students will also describe human activities that threaten deep-sea coral communities and describe actions that should be taken to protect resources of deep-sea coral communities.

Boom and Bust (from the 2003 Mountains in the Sea Expedition)
http://oceanexplorer.noaa.gov/explorations/03mountains/background/education/media/mts_boombust.pdf

Focus: Fishery management

Students will describe stages in a commercial fishery that eventually becomes severely depleted, interpret basic data to predict when a fishery stock is beginning to show signs of overexploitation, and describe the potential consequences of overexploitation on fish populations, marine habitats, and fishing businesses. Students will also describe and discuss potential management policies that could avoid or remediate overexploitation in commercial fisheries.

Other Resources

See page 215 for Other Resources.

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education settings.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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Scientific Posters

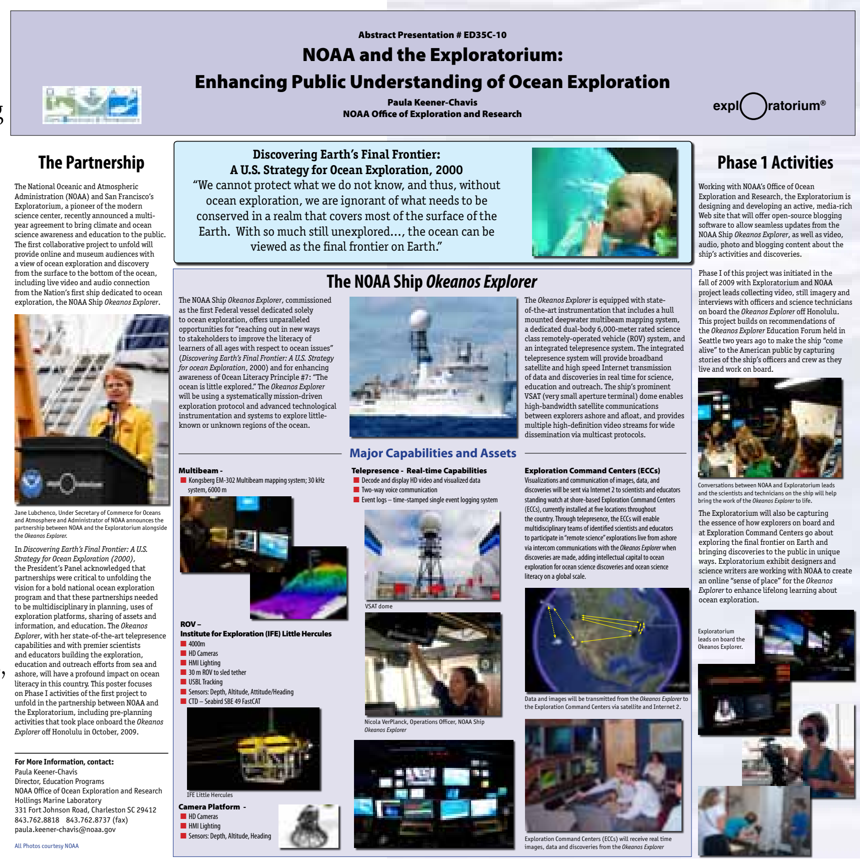
Scientific posters are an increasingly popular way to communicate results of scientific research and technical projects. There are a number of reasons for this, including limited time at conferences for traditional "public speaking"-style presentations, better options for interacting one-on-one with people who are really interested in your work, opportunities for viewers to understand the details of your work (even if you aren't present), and having a more relaxed format for those who dislike speaking in public. In addition, posters are more durable that one-time presentations; once they are created they can be used in many different settings, over and over again. For more discussion of pros and cons, as well as examples of good and bad posters, visit

http://www.swarthmore.edu/NatSci/cpurrin1/posteradvice.htm
http://www.ncsu.edu/project/posters/NewSite/
http://www.the-aps.org/careers/careers1/GradProf/gposter.htm

Scientific posters usually contain the same elements as traditional written reports: title, introduction, materials and methods, results, conclusions, literature cited (key citations only!), acknowledgments, and contact points for further information. Good posters do NOT usually have an abstract, though an abstract is often required as part of the submission process and may be included in a printed program.

Another similarity to traditional reports is that the best posters almost always go through several drafts. You should always expect that the first draft of your poster will change significantly before it emerges in final form. Be sure to allow enough time for others to review your first draft and for you to make needed changes.

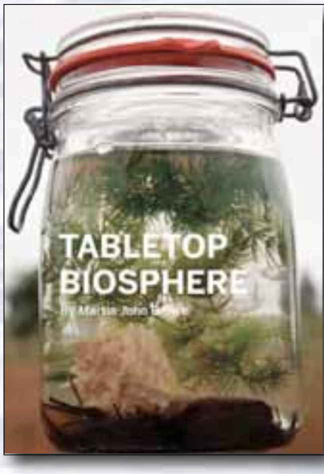
Below: An example of a scientific poster.



An important difference (and advantage) that posters have compared to written reports is that posters can be much more flexible in terms of layout and where these elements appear, as long as there is still a clear and logical flow to guide viewers through your presentation. Here are a few more tips for good scientific posters (see the Web sites listed above for many other ideas):

- Posters should be readable from 6 feet away;
- Leave plenty of white space (35% is not too much) -- densely packed posters can easily repel potential viewers;
- The top and right columns of your poster are prime areas for vital material, while the bottom edge will receive much less attention;
- Serif fonts (*e.g.*, Times) are easier to read than sans serif fonts (*e.g.*, Helvetica), so use sans serif fonts for titles and headings, and serif fonts for body text (usually no more than two font families on a single poster)
- Text boxes are easiest to read when they are about 40 characters wide

Tabletop Shrimp Support Module Construction Guide



From *Make*, Volume 10

NOTE: These procedures are adapted from *Ecosystems Engineering*, an article by Martin John Brown that appeared in Volume 10 of *Make* magazine. The article can be downloaded from *http://cachefly.oreilly.com/make/wp_aquanaut.pdf.*

Materials

Materials (for one module)

- 1 - 1 quart glass canning jar
- 3 - plastic containers, 1 quart capacity or larger
- 12 (approximately) - River pebbles, about grape-size; enough to cover the bottom of the glass jar in a single layer
- 3-4 - small shells
- 1 - Amano shrimp, *Caridina multidentata* (from an aquarium store)
- 4 - aquatic snails, each less than 1 cm overall length
- 8-inch stem of hornwort (*Ceratophyllum demersum*; from an aquarium store)
- Duckweed, approximately 2 inches x 2 inches (from an aquarium store or local pond)
- 2-8 - Amphipods (from a local pond)
- Pond sludge (from a local pond)
- Plastic bucket, 1 gallon or larger capacity

These materials may be shared by several groups:

- Fishnet or kitchen strainer
- Dechlorinating solution (for treating tap water; from an aquarium store)
- Solution of freshwater minerals (*e.g.*, "cichlid salts;" from an aquarium store)
- Calcium carbonate powder (from an aquarium store)
- Tablespoon measure

Procedure

1. Your teacher may provide some or all of the materials for your Tabletop Shrimp Support Module (TSSM), or you may be on your own. If you are responsible for rounding up the materials, you can obtain Amano shrimp, snails, hornwort, duckweed from an aquarium store. You can also obtain the dechlorinating and mineral solutions from an aquarium store, but you may want to partner with other groups since you don't need very much of either solution for one TSSM.

   You can get pond sludge from (you guessed it!) a local pond. Try to find one that has a shallow end where you can easily reach the bottom. Make your collection late in the afternoon, because this is when dissolved oxygen should be highest, and acidity lowest. The best places for collecting will be near aquatic plants and have a mixture of substrates such as sand, rock, and decaying wood. Collect the sludge from the pond bottom, and drag a fine-mesh net through the water as well. Ideally, you will collect a mixture of amphipods, copepods, and ostracods along with the sludge.

2. Make Nitrate-Poor Fresh Water (NPFW) by adding dechlorinating solution and mineral solution to a gallon of tap water according to directions on the packages. Your teacher may have you do this step with one or two other groups. The water from the pond or the aquarium store is likely to have a lot of algae and nitrates which would allow algae to take over the system. The use of NPFW helps to prevent this.

3. Rinse your 1-quart canning jar, rocks, and shells in the NPFW.

4. Fill your 1-quart canning jar halfway with NPFW. Put rocks in first, then shells, then the shrimp, snails, hornwort, duckweed, and 2 tablespoons of pond sludge. Be sure not to overload your system with extra animals or plants. Use only the amount specified!

5. Add more NPFW to your jar so that the top of the water is 1-inch below the top edge of the jar. Add 1 tablespoon of calcium carbonate powder (this will make the water cloudy for several hours because it dissolves slowly).

6. Place the cap tightly on the jar.

7. Place your ecosystem in a location that has temperature between 70°F and 80°F, and moderate light for about 12 - 16 hours per day. Do not put your system in direct sunlight.

8. Your TSSM is complete! Allow your system to equilibrate for at least a week before beginning any experiments.